Gender and age differences in vowel-related formant patterns: What happens if men, women, and children produce vowels on different and on similar F0?

Maurer, Dieter ; Suter, Heidy ; Friedrichs, Daniel ; Dellwo, Volker

DOI: https://doi.org/10.1121/1.4920812

Zürcher Hochschule der Künste
Zurich University of the Arts

Universität Zürich[UZH]

Gender and age differences in vowel-related formant patterns: What happens if men, women, and children produce vowels on different *and* on similar F0?

Dieter Maurer[1], Heidy Suter[1], Daniel Friedrichs[2], Volker Dellwo[2]
[1] Institute for the Performing Arts and Film, Zurich University of the Arts, Switzerland, [2] Phonetics Laboratory, University of Zurich, Switzerland
dieter.maurer@zhdk.ch, heidy.suter@zhdk.ch, daniel.friedrichs@uzh.ch, volker.dellwo@uzh.ch www.phones-and-phonemes.org

169th Meeting of the Acoustical Society of America

The Journal of the Acoustical Society of America 04/2015; 137(4):2416-2416.
DOI:10.1121/1.4920812

Abstract

There is a broad consensus in the literature that vowel-specific formant patterns differ as a function of gender (men vs women) or age (adults vs children) due to different average vocal tract sizes [1, 2]. Although an additional influence of fundamental frequency F0 is discussed in corresponding normalisation approaches, formant patterns relating to sounds of adults and children that exhibit the same F0, to sounds of adults with higher F0 than sounds of children, and to sounds of men with higher F0 than sounds of women are barely compared. Therefore, we investigated vowel sounds of men, women, and children producing sounds for three conditions of comparison: (1) F0 according to statistical levels for vowels produced in word-citation form, (2) similar F0 for men, women, and children compared, and (3) higher F0 for adults than for children, and higher F0 for men than for women. In the present paper, on the basis of a large scale investigation of vowel sounds at very different levels of F0, first observational results are reported and illustrated.

[1] Peterson, G.E., Barney, H.L. (1952): Control methods used in a study of the vowels. J. Acoust. Soc. Am., 24/2, 175–184.
[2] J. Hillenbrand, J., Getty, L.A., M.J. Clark, and K. Wheeler, "Acoustic characteristics of American English vowels," J. Acoust. Soc. Am., vol. 97, no. 5, pp. 3099–3111, 1995.

Questions

(1) Do gender and age-related differences in vowel-specific formant patterns persist, if F0 of the sounds compared is similar?

(2) What about gender and age-related differences in vowel-specific formant patterns, if F0 of the sounds compared is higher for adults than for children, or higher for men than for women?

Method

Basis: A large-scale investigation of sounds of the German vowels /i–y–e–ø–ɛ–a–o–u/ produced by trained and untrained speakers (42 speakers, men, women, children) on different levels of F0, spanning their entire vocal range, and with three levels of vocal effort, i.e., medium, high, and low (see [3]).

Recordings related to the present study: The speakers produced isolated sounds of the vowels on F0 of C3 (men), G3 (adults), and A3–C4–E4 (all speakers), i.e., 131–196–220–262–294–330 Hz, accounting for the methodological limitation of formant frequency calculation for F0 > 350 Hz. However, for /i–y–u/, A4–C5–E5 (440–523–659 Hz, all speakers) were added because, for these sounds, the first harmonic is clearly dominant in general, and F1 can be assumed as nearby.

Acoustic analysis and listening test: An acoustic analysis for mid-portions of 0.3 sec of the sounds was conducted (LPC curves, formant frequencies, dominant harmonics), and five professionally trained singers and actors of the Zurich University of the Arts assigned the perceived vowels in a listening test.

Direct comparisons: For each vowel, sounds of single speakers different in gender and age were compared. The selection of speakers and sounds was related to vowel perception (identification ≥ 80 %, i.e. 4/5 listeners) and to comparable harmonic spectra an dominant harmonics < 1.5 kHz for similar F0 levels.

Observational results

F0 condition (1), F0 levels = 131 Hz for men, 220 Hz for women, 262 Hz for children: In general, F1 and F2 were found to differ according to the statistical values as given for vowels produced in citations-form words. However, exceptions occurred, above all for sounds of /i/, /y/, and /u/ (for an example, see Figure 2).

F0 condition (2), F0 levels = 220 Hz for men and women, and F0 = 262 Hz for adults and children: In many direct comparisons of sounds in similar F0 of a man, a woman, and a child, we observed a decrease or even a disappearance of the expected speaker-group differences in the formant frequencies < 1.5kHz.

F0 condition (3), F0 levels = higher for men than for women, and F0 = higher for adults than for children: In a substantial part of direct comparisons of single speakers, concerning sounds on higher F0 for the man than for the woman, or sounds on higher F0 for the adults than for the child, we observed an "inversion" of the expected speaker-group differences < 1.5 kHz, i.e., higher formants for the sounds of the man than of the woman, and higher formants for the sounds of the adults than of the child.

Formants > 1.5 kHz: No corresponding consistent observations were made concerning the formants > 1.5 kHz.

Illustration: See examples for /o/ and /i/ (all three conditions) in Figure 1 and 2.

Discussion

The present observational findings support earlier indications [4] that gender and age-related differences in the lower formants < 1.5 kHz, as given in vowel formant statistics for citation-form words, decrease or disappear for similar levels of F0 of comparison. This finding anew calls for a further examination of the role of F0 when interpreting speaker-group related differences in formant patterns.

Because "inversion" of expected speaker-group differences in format frequencies < 1.5 kHz for sounds on higher F0 for men than for women, and for adults than for children, were also observed, we conclude that these findings confirm a major impact of F0 on the lower formants < 1.5 kHz (for earlier indications, see [5-7]).

These findings provide further evidence for the claim that, in future investigations on the normalisation of the acoustic characteristics of vowel sounds produced by men, women, and children, F0 of the sounds compared must be accounted for in principle. However, future research should also address the role of vocal effort, F0 position in the vocal range of a speaker (including register changes), and style or mode of vowel production. Finally, an inclusion of different phonation types, above all whispered, breathy, and creaky phonation, may provide further clarification.

[3] Maurer, D., Suter, H., Friedrichs, D., Dellwo, D. (2015): Acoustic Characteristics of Voice in Music and Straight Theatre: Topics, Conceptions, Questions. In A. Leemann, M.-J. Kolly, S. Schmid, V. Dellwo (Eds.), Trends in Phonetics in German-speaking Europe. Frankfurt: Peter Lang (in print).
[4] Maurer, D., Cook, N., Landis, L., d'Heureuse, C. (1992): Are measured differences between the formants of men, women and children due to F0 differences? J. Int. Phonetic Assoc., 21, 66–79.
[5] Maurer, D., Landis, T. (1995): F0-dependence, number alteration, and non-systematic behaviour of the formants in German vowels. Int. J. Neurosci., 83, 25–44.
[6] Maurer, D., Landis, T. (1996): Intelligibility and spectral differences in high pitched vowels. Folia phoniatrica et logopaedica, 48, 1–10.
[7] Maurer, D., d'Heureuse, C., Landis, T. (2000): Formant pattern ambiguity of vowel sounds. Int. J. Neurosci., vol. 100, pp. 39–76.

Illustration

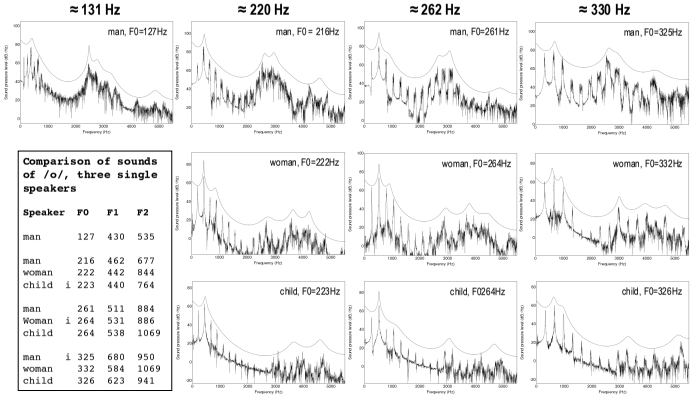

Figure 1: Comparisons of sounds of /o/ are of special interest because the F0-dependence of the vowel-related lower spectrum can be observed for F0 clearly below statistical F1 (related to citation-word form). Thus, the phenomenon does not concern "oversinging" of the first formant frequency. The above series of vowel spectra shows vocalisations of the vowel /o/ produced by a man, a woman, and a child, on F0 levels of C3 (man, 131 Hz) and A3–C4–E4 (all speakers, 220–262–330 Hz). The series illustrates a possible disappearance of expected gender and age-related differences for F1 on similar F0 of the sounds, and „inverted" F1 for "inverted" F0 (marked as "i"). Most of the sounds show only one lower spectral peak and the corresponding calculated F2 level is weak.

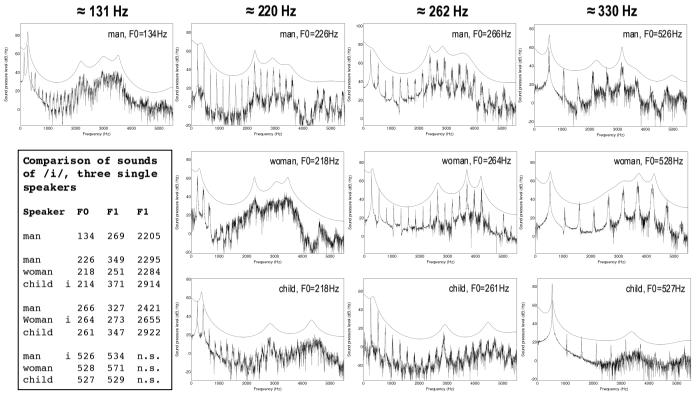

Figure 2: Comparisons of sounds of /i/ are of special interest because statistical F1 (related to citation-form words) can easily be "oversung" without a change in the perceived vowel quality. The above series of vowel spectra shows vocalisations of the vowel /i/ produced by a man, a woman, and a child, on F0 levels of C3 (man, 131 Hz) and A3–C4–C5 (all speakers, 220–262–523 Hz). Comparing the sounds of the man and the woman, the series illustrates an exception of gender-related differences in F1, and „inverted" F1 for "inverted" F0 (marked as "i"). Comparing the sounds of the man and the child, the series illustrates again possible disappearance of expected age-related differences for F1 on similar F0 of the sounds, and „inverted" F1 for "inverted" F0. (Note that, for the high-pitched vowel, F2 was not calculated because of methodological problems of formant estimation on F0 > 350 Hz. However, the calculated frequency of F1 is near the frequency of F0, and the first harmonic is clearly dominant.)